In-situ Studies of the Electric Field Dependence in $PbZn_{1/3}Nb_{2/3}O_3$-$PbTiO_3$ Crystals

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Beamline(s): **X17B1, X7A**

Solid solutions of $Pb(Zn_{1/3}Nb_{2/3})O_3$ containing a few percent of $PbTiO_3$ (PZN-PT) are relaxor ferroelectrics, which have a piezoelectric response an order of magnitude larger than those of conventional piezoelectric ceramics[1, 2] when the rhombohedral crystals are poled along the <001>directions, despite the fact that the polar axis lies along [111]. It has been reported that by applying an electric field along the [001] direction a rhombohedral-to-tetragonal phase transition is induced [3]. Our current study gives very different results. We show that the high-field phase observed in PZN-8%PT is not tetragonal but monoclinic.

The measurements were initially performed at X7A, with x-rays of about 18 keV. The scans showed very broad peaks, indicative of a strong "skin" effect (see Fig. 1) in the direction perpendicular to the field. Due to the high lead content, the samples are quite opaque at these energies, with a penetration depth of only about 1 μm, at the typical scattering angles used, and the measurements are therefore sensitive to inhomogeneous piezoelectric strains close to the surface. In order to avoid this effect, high energy x-ray experiments were performed at 67 keV at X17B1 with an electric field applied in-situ. At the bottom of Fig. 1 the (400) and (040) reflection profiles for three different field values are plotted. It is clear that the position of the (400) peak shifts towards lower angles as the field is increased, while that of the (040) peak, corresponding to a lattice parameter of 4.030 Å, remains unchanged, as shown also in Fig. 3. The markedly different widths of these two peaks has led to postulate the coexistence of two phases (monoclinic and tetragonal) at E= 0 kV/cm, with very different domain sizes [3].

The results obtained with high energy x-rays, shown in Fig. 2 confirm that the broadening observed for the (h00) peaks is merely a "skin" effect. Fig. 2 shows the same reflections as in Fig. 1, at 67 keV. These scans revealed no broadening and a symmetric splitting due to the monoclinic distortion is observed

Fig. 3 shows the evolution of the lattice parameters with electric field between the high-field monoclinic phase and the zero-field orthorhombic phase (a_m= c_m). a_r and a_p and c_p correspond to the as-grown and the just-poled crystals, respectively. The lattice parameter, c_m, along the field direction, shows the characteristic hysteresis loop. Both high and low energy experiments showed the same features along this direction.

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References: [1] J. Kuwata, K. Uchino, and S. Nomura, Japan. J. of Applied Phys., **21**, p.1298 (1982). [2] S. Park and T. Shrout, J. Appl. Phys., **82**, p. 1804 (1997). [3] M. Durbin, J. Hicks, S. Park, and T. Shrout, J. Appl. Phys., **87**, p. 8159 (2000).

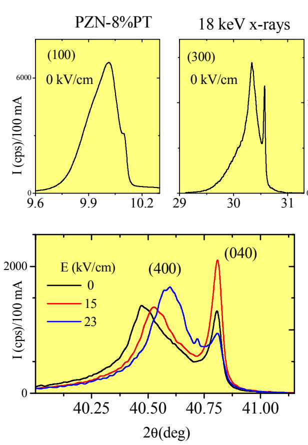

Figure 1. Scans along [100] with 18 keV x-rays showing two Bragg peaks with very different FWHMs.

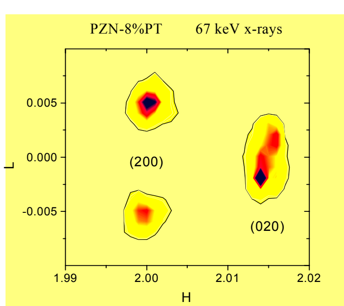

Figure 2. H0L scans with 67 keV x-rays showing the same two lattice spacings than in Figure 1.

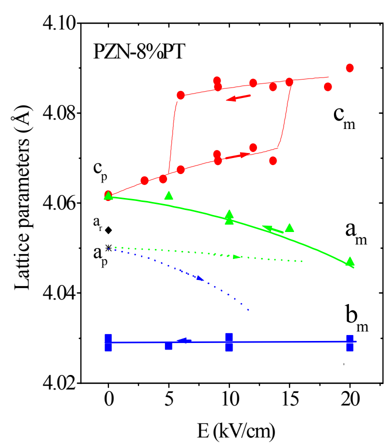

Figure 3. Evolution of the lattice parameter with the electric field applied *in-situ*.